

EXPLOITATION, RESERVES AND TRANSPORT OF NATURAL GAS IN THE REPUBLIC OF CROATIA

Josipa Velić, Dragan Krasić, Ivan Kovačević

Preliminary notes

21 427,128×10⁶ m³ of natural gas were exploited from 2003 to 2010. In contrast to the gas production trend from the Adriatic, the production decline in the Pannonian Basin area is apparent. Croatian proven reserves of natural gas are 76 903,991×10⁶ m³ of which 26 216,393×10⁶ m³ are economically exploitable. 12 223,770×10⁶ m³ are from the Adriatic and 13 992,623×10⁶ m³ from the Pannonian Basin. A decline in domestic exploitation is implied after 2014 when imported volumes will be equal to the exploited thus affecting the economy and other consumers. Estimated 7×10⁹ m³ of natural gas will be imported in 2030. Length of the gas transportation system in Croatia is 2113 km which includes exploitation, PSP Okoli, 37 distribution systems and 27 end consumer pipelines. Three future import routes are possible: Nabucco, Southern stream and IAP (Ion-Adriatic Pipeline). LNG terminal construction should give a great contribution for further development of Croatia's energy system and economy.

Keywords: Croatia, exploitation, natural gas, reserves, transport

Pridobivanje, rezerve i transport prirodnog plina u Republici Hrvatskoj

Prethodno priopćenje

Od 2003. do 2010. iscrpljeno je 21 427,128×10⁶ m³ prirodnoga plina. Uočljivo je opadanje pridobivanja plina unutar Panonskoga bazena. U Jadranskom podmorju je suprotno. Hrvatska ima 76 903,991×10⁶ m³ preostalih ukupno utvrđenih rezervi prirodnoga plina. Preostalih bilančnih rezervi ima 26 216,393×10⁶ m³; od toga je 12 223,770×10⁶ m³ u Jadranskom podmorju, a 13 992,623×10⁶ m³ u Panonskom bazenu. Procijenjeno smanjenje domaće eksploatacije nakon 2014., kada će se uvoz i domaća eksploatacija izjednačiti, bitno će utjecati na gospodarstvo i ostale potrošače. Prema predviđanjima uvožit će ga se u 2030. oko 7 milijardi m³. Dužina transportnog sustava plina u Hrvatskoj je 2113 km na koji je priključeno pridobivanje, PSP Okoli, 37 distribucijskih sustava i 27 izravnih plinovoda krajnjih kupaca. Moguća su tri dobavna pravca: Nabucco, Južni tok i IAP (Ion-Adriatic Pipeline). Izgradnja LNG terminala trebala bi dati snažan doprinos daljnjem razvoju hrvatskog energetskog sustava i gospodarstva.

Ključne riječi: Hrvatska, pridobivanje, prirodni plin, rezerve, transport

1

Introduction

For a number of years oil and its products have held a primary role in every aspect of distribution and energy consumption. The recent dynamics of the World energy scenario dictates the increase in the usage of the world's fastest growing energy resource – natural gas. These kinds of growth trends and globalization raise a need in infrastructure and technology investments. Estimated global consumption of natural gas by the 2020 would double which would strengthen the role of the Russian Federation as a great exporter while the United States of America will be even more dependent on the import of this natural resource. As a result, the centres of economic power may greatly shift.

European countries are highly dependant on the import of natural gas from the Russian Federation. This market is interrupted by the changes in politics between Ukraine, as a transit country for natural gas, and the Russian Federation. Consequences of these political disputes are occasional interruptions in natural gas transport through Ukraine in the time of the peak consumption thus making the natural gas a first rate political weapon.

As a consequence, the Republic of Croatia should search for an alternate solution that would prevent these "gas crises" or ease their affect. Examples are the crises in 2006 and 2009. For this purpose, from 1990 a terminal for liquefied natural gas (LNG) was planned to be built in the Republic of Croatia. Advantages of LNG are numerous – stable output levels, lower pollution level and its price in contrast to oil.

Exploitation of gas in the period from 2003 until 2010 will be presented in this paper along with the natural gas reserves – from the total established to the remaining balance reserves. The idea is, from studying the near past trends, to predict the future trends in gas consumption and exploitation by the petroleum geology approach.

2

Problem overview

Tradition of natural gas exploitation, transport and consumption in the Republic of Croatia is over 90 years long and is set only for meeting local demand. Investments were made only in the local distribution network in the northern and eastern part of the country. This is due to all gas fields being situated in the Croatian part of the Pannonian Basin until recently. In 1977, an important connection in the gas system with the Republic of Slovenia was made in the Rogatec – Hum na Sutli point. In the same year, a long lasting import route from the Russian Federation was established. The same route was a new found possibility for the Slovenian company Geoplina to store natural gas in underground gas storage PSP Okoli which has the storage capability of 553×10⁶ m³. Considering the yearly needs, 40 % was imported from the Russian Federation (1,15×10⁹ m³) while the rest came from domestic exploitation which is about 2×10⁹ m³ per year. Interruptions in the transport in the import routes along with the decline in domestic exploitation after 2014, when the volume of imported and natural gas from domestic exploitation will equalize (Fig. 1), will have a great impact on the economy and consumers. Because of these trends, a new solution for the import of natural gas is being sought. According to predictions, by 2030 the imported volume of natural gas will be 7×10⁹ m³.

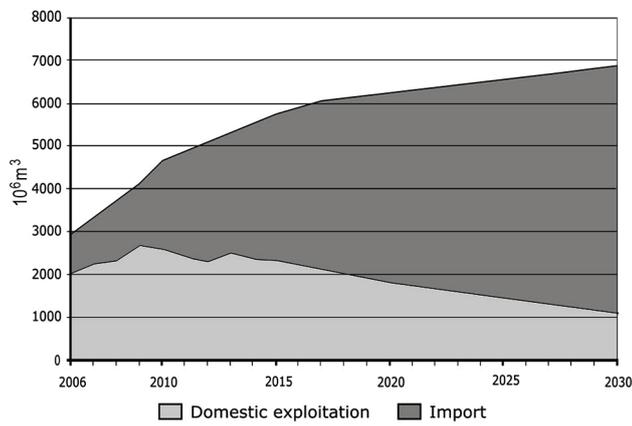


Figure 1 Estimation of future exploitation and import volumes of natural gas

3 Great regional gas pipelines

Despite excellent geographic position and favourable geologic and geomorphologic position of the Republic of Croatia, great regional gas pipelines tend to go around it. All the aforementioned characteristics are pronounced in excellent road and good railway and electro energetic connection and infrastructure.

Natural gas network inside the borders of the Republic of Croatia is being slowly upgraded but the problem of regional connection is still not being adequately addressed. Future gas crises, as those between the Russian Federation and Ukraine in 2006 and 2009, are trying to be averted with the introduction of new regional

gas pipelines or by building LNG terminals on the coastline. New alternative routes of gas import are more and more important because of the future prediction of increase in gas import volumes and the decline in domestic production.

The government of the Republic of Croatia and Plinacro d.o.o. Zagreb (company that is totally owned by the State) started to modernize the local gas pipelines in 2002. Planned modernization would be done in two periods.

1st period started in 2006 and was successfully finished in 2006. During this period, several gas pipelines were made in the central and eastern Croatia as well as the Karlovac-Pula pipeline (Fig. 2). However, the biggest achievement of the first period of modernization was the connection of gas fields in the Adriatic via underwater gas pipeline with the gas terminal in Pula. This project is known as "Mala Gea" and was done by Plinacro d.o.o. Zagreb, INA-Industrija nafte d.d. Zagreb, and Italian company ENI (*Ente Nazionale Idrocarburi*). Completion of this project made the direct transport of exploited natural gas possible in the Adriatic offshore first to Pula and later to Slavonski Brod in 75 bar capable gas pipeline. Prior to the project completion, gas had to be transported via transport systems of the Republic of Italy and the Republic of Slovenia. In the future, the newly built gas pipeline could be used for gas import from the Republic of Italy or the countries from North Africa. First period established the so called "backbone" of gas transport for the Republic of Croatia.

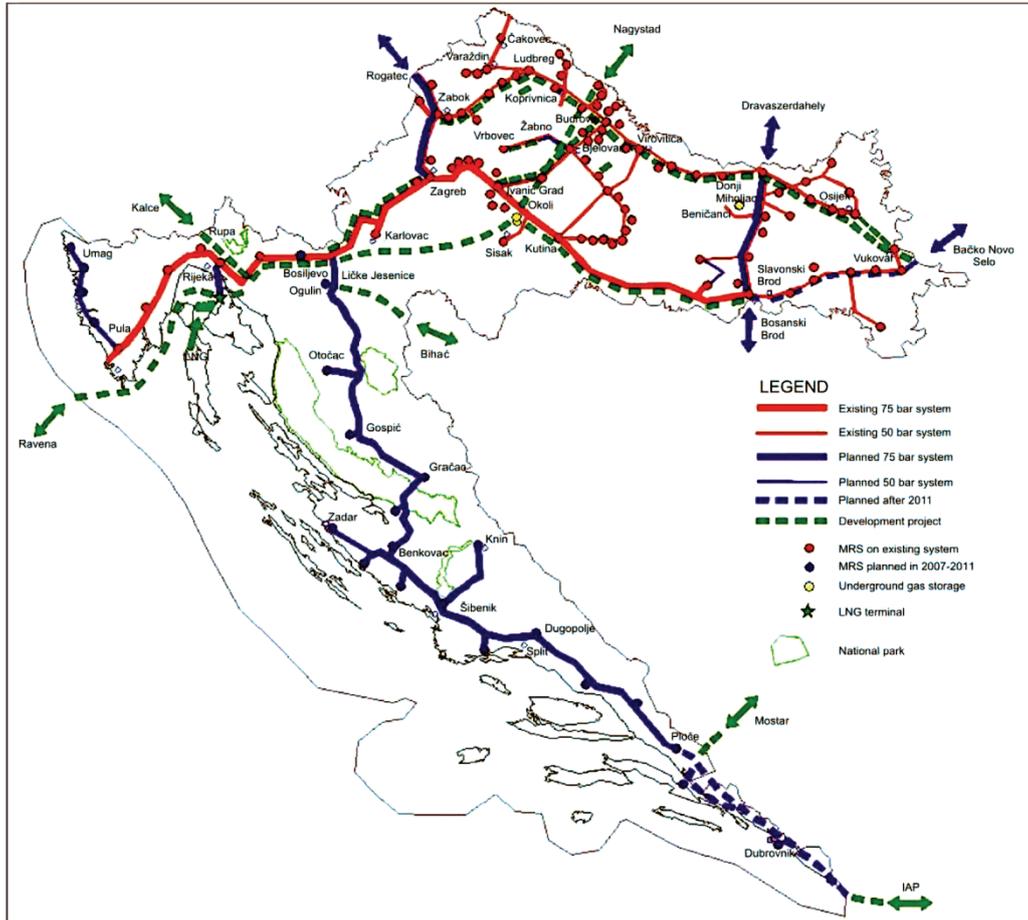


Figure 2 Natural gas transportation system in the Republic of Croatia

2nd period lasted from 2006 to 2011. In that project period, construction of the gas pipeline Bosiljevo-Split (in later phase Split-Dubrovnik) was of the greatest importance. Furthermore, new gas pipeline between the Republic of Hungary and the Republic of Croatia was established between Donji Miholjac – Dravaszerdahely. Future projects are further development of international gas pipelines with Bosnia and Herzegovina which will connect Donji Miholjac through Slobodnica to Bosanski Brod, and enhancement of the gas transport capacity by building a new gas pipeline between Rogatec and Zabok. Further development of smaller local gas pipelines is also planned.

The length of the gas transport system in the Republic of Croatia is 2113 km which includes pipelines from the offshore Adriatic and gas fields in the Pannonian Basin area as well as PSP Okoli, 37 distribution systems and 27 pipelines that go directly to end consumer. Considering the circumstances, new transport routes for gas from Eurasia and Africa should be obtained. One route is already possible – the aforementioned through the Republic of Italy. For stabilizing gas distribution system, a new underground storage at Grubišno Polje is being planned as well as new LNG terminal. At present, three additional gas transport routes are available to regional continental gas pipelines – Nabucco, South Stream and IAP (*Ion-Adriatic Pipeline*).

Gas pipeline **Nabucco** is a project for minimizing European dependence on oil and gas from the Russian Federation. The plan is to connect Erzurum in the Republic of Turkey and Baumgarten an der Marcha in the Republic of Austria. Gas would be transported from Central Asia and the Middle East. The project completion is estimated for 2015 with pipeline length of 3300 km and transfer capacity of 31×10^9 m³ of natural gas per year with minimal duration of 40 years. The Republic of Croatia's participation in the project can only be obtained through a pipeline to the Republic of Hungary.

South Stream is a project financed by the Russian Gazprom and Italian ENI. Construction started in 2010 while the completion is planned for 2015. This pipeline should connect the Russian Federation with the rest of Europe through the Black sea, the Republic of Bulgaria, the Republic of Serbia and the Republic of Hungary. Of interest to the Republic of Croatia is a spur of the South Stream which will go through our country, across the Republic of Slovenia and to the Republic of Austria. Also considered is the "*South spur*" which goes from the Republic of Bulgaria to the Republic of Italy, via Greece. Through it, and via IAP, a connection of the Republic of Croatia to the IGI (*Italy-Greece Interconnector*) can be obtained.

The Ion-Adriatic Pipeline (IAP) should connect the Republic of Croatia through the Republic of Montenegro and Republic of Albania to IGI at Solun in Greece. IAP should be finished by 2012 with the length through the Republic of Croatia of 130 km. Through it, the excess of 5×10^9 m³ of natural gas would be transferred to aforementioned countries and Bosnia and Herzegovina.

All the great regional pipelines could not function if a system of gas hubs was not established. Although some countries buy gas on the basis of long term agreements, like the Republic of Croatia does from the Russian

Federation, liberalization of the market and stock market type of trade is being established which is a much more flexible type of trading.

The oldest gas hub in Europe is located in Great Britain – *National Balance Point (NBP)* which exists from 1996. Due to geographic isolation, this is not the most important hub. Except the one in Great Britain, there are few others in Europe – *Title Transfer Facility (TTF)* in the Kingdom of Neatherland, Zeebrugge (Kingdom of Belgium), Baumgarten (Republic of Austria), Lemertheim and others. The gas prices are mostly determined by the prices of crude oil – gas to oil pricing. The ownership of the gas is determined within the pipeline or network of pipelines. For the Republic of Croatia and South-eastern Europe, the most important hub in the future could be the Baumgarten. It should have a great role in the sale of gas from the planned LNG terminal in Omišalj.

4

Liquid natural gas terminals

Liquefied natural gas (LNG) is a clear, noncorrosive; cryogenic fluid cooled to -162 °C at a normal pressure and is mostly comprised of methane. Its volume is reduced about 600 times by cooling and by doing so it can be transported by tankers. Fluid is odourless and colourless with density less than water so in the case of spill it would not sink, but float on the water surface until it evaporates. Natural gas in LNG terminals is firstly cleansed from any other ingredients – propane, ethane, butane, nitrogen, water, etc., after which it is cooled to the aforementioned temperature. Afterwards it is transported by tankers to LNG terminals where it is gasified and transported through pipelines to end consumers.

LNG is different from LPG (*Liquified petroleum gas*) which is derived during the refining of crude oil. LPG is stored in small tanks and it is very flammable and explosive. On the contrary, LNG is not explosive in open spaces, inert and neither poisonous nor carcinogen. There is a contract by which the new terminal should be built near existing Dina-Petrokemija d.d. in Omišalj on the island Krk. Location of LNG terminal near the Plomin bay in Istria has been rejected. Possibility of building large tanks, great enough sea depths in the vicinity of the installations, topography, geotechnical and geological features with already existing infrastructure were the key in the selection of the future position of LNG terminal. The terminal in Omišalj will be used as an inflow terminal, and also for trans-shipment, storage of LNG in special tanks and its gasification. Yearly, an expected traffic of 100 ship loads is estimated. Approximate time for offloading one ship is no more than 25 hours. LNG terminal capacity would be $(10-15) \times 10^9$ m³ per year, which is four times greater than the current demand of the Republic of Croatia, with a lifetime of more than 30 years.

LNG terminal is a much safer and cheaper solution than regional pipelines which is recognized in World gas trading trends. At present, LNG constitutes 21 % of total traded gas volumes with anticipated one third by 2020.

4

Exploitation of natural gas in the Republic of Croatia from 2003 to 2010

The exploitation of natural gas in the Republic of Croatia has been addressed previously only several times [1, 2, 3] but for the Pannonian part and in less detail.

By the article 18 of the Ordinance of data acquisition, methods of evidence and establishing the reserves and for making their balance sheets [4, 5] it is determined that the established reserves of oil, condensate and natural gas that can be exploited economically with current methods fall in the category of balance reserves. By the article 19 of the aforementioned Ordinance it is determined that the reserves of oil, condensate and natural gas fall in off-balance reserves when:

- they cannot be exploited by current known methods (unexploitable) or
- they cannot be economically exploited with current methods (unprofitable).

Total established reserves consist of all reserves on the day of reserves calculation and are made out of exploitable reserves up to the date of reserves calculation along with remaining balance and off-balance reserves determined on the aforementioned day. Volumes of established reserves in this article are calculated on 31st of December, 2010.

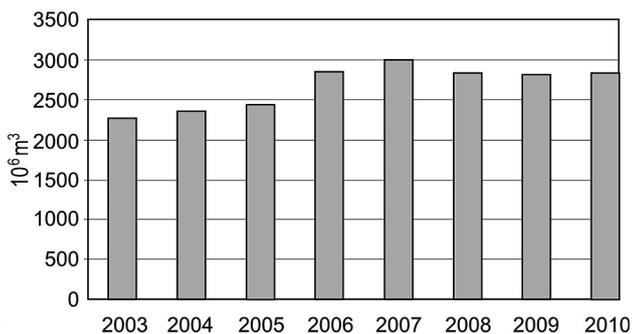


Figure 3 Yearly exploitation of natural gas from 2003 to 2010

Remaining reserves consist of remaining balance and off balance reserves. Volume of these reserves presented in this article is also calculated on 31st of December, 2010.

Overview of the dynamic of natural gas exploitation is given for the time period from 1st of January 2003 to 31st of December 2010. Data used for discussion in this paper were acquired from the Ministry of Economy, Labour and Entrepreneurship, Directorate of Mining, and were presented in Balance sheet of the state of mineral resources of the Republic of Croatia on the 31st of December, 2010.

In the Republic of Croatia natural gas is present at 60 exploitation objects – fields. Additionally, research is ongoing on 11 research areas. Exploitation of natural gas in the time period from 1st of January 2003 to 31st of December 2010 was active on 49 hydrocarbon fields. These fields are not exclusively natural gas fields but may comprise oil and/or condensate in addition to natural gas. Few examples of these circumstances are hydrocarbon fields "Okoli", "Legrad", "Žutica" and "Đeletovci".

In the aforementioned eight year time period 21 427,128×10⁶ m³ of natural gas were exploited (Tab. 1, Fig. 3).

Year 2007 was the peak year in an eight year exploitation period. The lowest amounts of exploitation were registered in 2003 with the amount of 2 278,250×10⁶ m³. Fig. 3 clearly describes natural gas exploitation trend for the studied period with a general increase in production between 2006 and 2010.

When comparing the exploited volumes from two exploitation regions in the Republic of Croatia, more natural gas was exploited from the Pannonian Basin region (10 981,260×10⁶ m³) than from the Adriatic offshore (10 445,890×10⁶ m³) (Fig. 4).

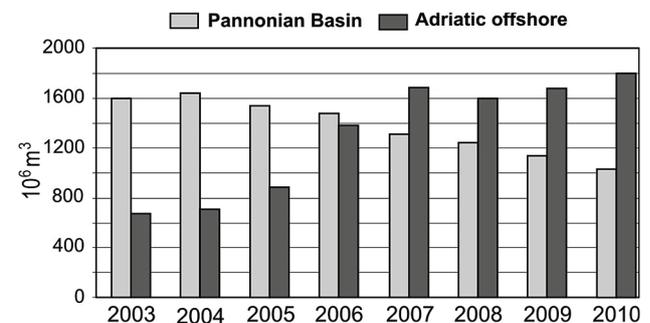


Figure 4 Exploitation of natural gas in the Pannonian Basin and the Adriatic offshore (2003-2010)

Peak exploitation years were 2003 and 2004 for the Pannonian region and 2007 and 2010 for the Adriatic offshore. An opposite trend in the exploitation trend thus may be observed from these two regions (Fig. 5).

Greatest exploited amounts of natural gas were from the **Drava Depression** in the Pannonian Basin region. A total of 9 313,18×10⁶ m³ (Fig. 6) was exploited which accounts for almost a half of the entire natural gas exploitation of the Republic of Croatia up to date. Peak exploitation year was 2004 with the volume of 1 350,21×10⁶ m³. Exploitation fields in this area are "Molve", "Kalinovac", "Gola", "Stari Gradac", "Beničanci" and "Šandrovac" but 80 % of exploited volumes come from "Molve" and "Kalinovac". The majority of the fields in this area have a negative exploitation trend with the exception of the fields "Gola", "Šandrovac" and "Bilogora".

Table 1 Yearly exploitation of natural gas from 2003 to 2010

	Year								Total
	2003	2004	2005	2006	2007	2008	2009	2010	
Yearly exploitation (10 ⁶ m ³)	2 278,250	2 352,249	2 432,422	2 863,698	3 001,042	2 847,175	2 819,069	2 833,223	21 427,128

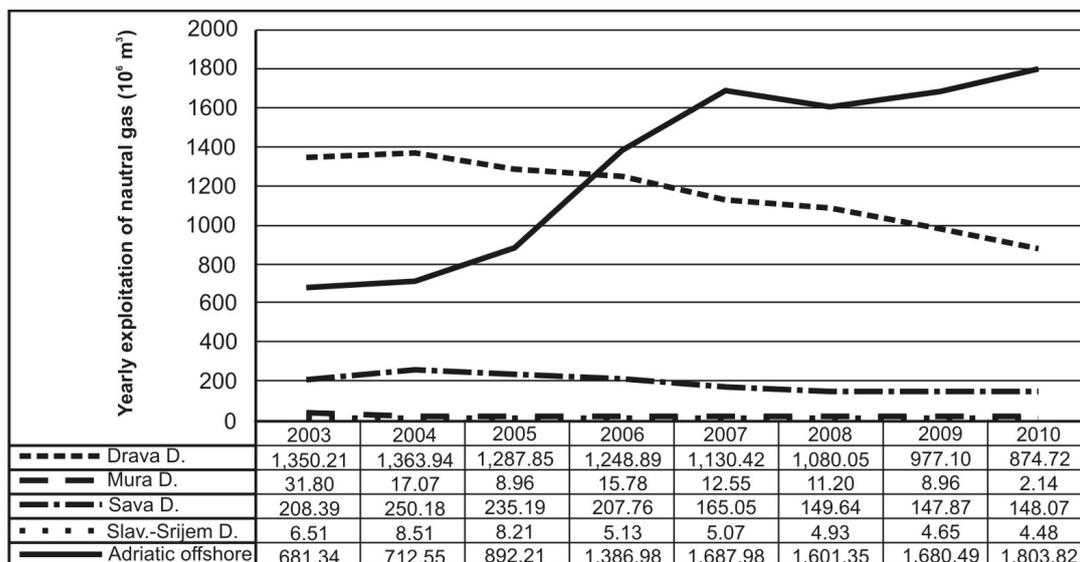


Figure 5 Exploitation of natural gas shown separately for Depressions and the Adriatic offshore from 2003 to 2010 in 10^6 m^3

Table 2 Average yearly and daily exploitation of natural gas from 2003 to 2010

Year	Exploitation of natural gas (10^6 m^3)	Depression				Pannonian Basin – total	Adriatic offshore
		Drava	Mura	Sava	Slavonia-Srijem		
2003	Total	1 350,210	31,800	208,390	6,510	1 596,910	681,340
	Per day	3,700	0,090	0,570	0,020	4,380	1,870
2004	Total	1 363,940	17,070	250,180	8,510	1 639,700	712,550
	Per day	3,740	0,050	0,690	0,020	4,490	1,950
2005	Total	1 287,850	8,960	235,190	8,210	1 540,210	892,210
	Per day	3,530	0,020	0,640	0,020	4,220	2,440
2006	Total	1 248,890	15,780	207,760	5,130	1 477,560	1 386,150
	Per day	3,420	0,040	0,570	0,010	4,050	3,800
2007	Total	1 130,420	12,550	165,050	5,070	1 313,090	1 687,980
	Per day	3,100	0,030	0,450	0,010	3,600	4,620
2008	Total	1 080,050	11,200	149,640	4,930	1 245,820	1 601,350
	Per day	2,960	0,030	0,410	0,010	3,410	4,390
2009	Total	977,100	8,956	147,871	4,646	1 138,573	1 680,490
	Per day	2,670	0,020	0,400	0,010	3,120	4,600
2010	Total	874,721	2,142	148,065	4,475	1 029,400	1 803,820
	Per day	2,390	0,005	0,400	0,010	2,820	4,940
2003 ÷ 2010	Total average	1 164,148	13,557	189,018	5,935	1 372,658	1 305,736
	Per day average	3,189	0,036	0,516	0,014	3,761	3,576

Exploitation of natural gas from the **Sava Depression** in the aforementioned eight year period was $1 512,15 \times 10^6 \text{ m}^3$ with the exploitation peak in 2004 (Fig. 5). In addition to the greatest fields in this area, "Žutica" and "Okoli", the fields "Lipovljani", "Jamarica" and "Stružec" also have a great influence on exploitation volumes. Negative natural gas exploitation trend in the Sava Depression is not as emphasized as in the Drava Depression – this region has a more stable exploitation trend.

Although the **Mura Depression** has natural gas exploitation volumes three times greater than the Slavonia-Srijem Depression, they are very small when compared to the ones from the Sava or Drava Depression (Tab. 2). Most favourable year was 2003 after which a 50 % decline in exploitation was recorded. Almost all exploited natural gas volumes in the studied eight year period come from the field "Legrad" with addition of very small volumes from the field "Mihovljan".

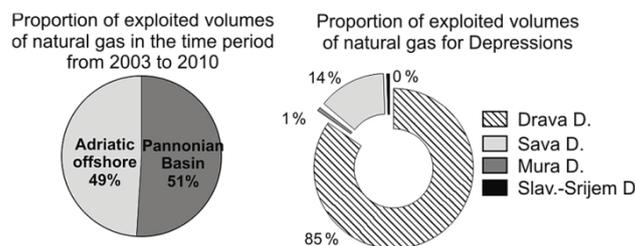


Figure 6 Proportion of exploited volumes of natural gas for Depressions (from 2003 to 2010)

The lowest amounts of natural gas were exploited from the Slavonia-Srijem Depression. Peak exploitation year was 2004 with only $8,510 \times 10^6 \text{ m}^3$ (Tab. 2). Exploitation was an average $20 000 \text{ m}^3$ per day from three fields – "Đeletovci", "Ilača" and "Privlaka". A decline in exploitation is apparent.

The Adriatic offshore region is characterized by an increase in natural gas exploitation volumes over the studied eight year period. The greatest increase in exploitation was recorded in 2007 (Tab. 2). A total of 49 % of entire natural gas volumes in the studied eight year period was exploited from this region and only from two exploitation fields. Natural gas is exploited from gas fields "Marica" and "Katarina", from exploitation field "Marica" and "Ana", "Annamaria", "Ida", "Ika", "Irina" and "Ivana" from exploitation field "Sjeverni Jadran". Gas fields that are still not in exploitation are "Božica" from exploitation field "Sjeverni Jadran" and "Izabela" from exploitation field "Izabela". Greatest volumes of natural gas are exploited from "Sjeverni Jadran" area. Total exploited volumes for an eight year period are $8\,692,324 \times 10^6 \text{ m}^3$ with a daily exploitation of more than $3,5 \times 10^6 \text{ m}^3$ (Tab. 2).

5 Balance and out of balance natural gas reserves

The Republic of Croatia has a volume of $76\,903,991 \times 10^6 \text{ m}^3$ total remaining established reserves of natural gas. Almost two thirds of this volume is from the Pannonian Basin region (Fig. 7 and Fig. 8). If only balance reserves (Fig. 9) of $26\,246,393 \times 10^6 \text{ m}^3$ are taken into consideration then the reserve ratio for the two regions is different. In that case, the remaining balance reserves from the Adriatic offshore are $12\,223,770 \times 10^6 \text{ m}^3$ while the ones from the Pannonian Basin area are $13\,992,623 \times 10^6 \text{ m}^3$.

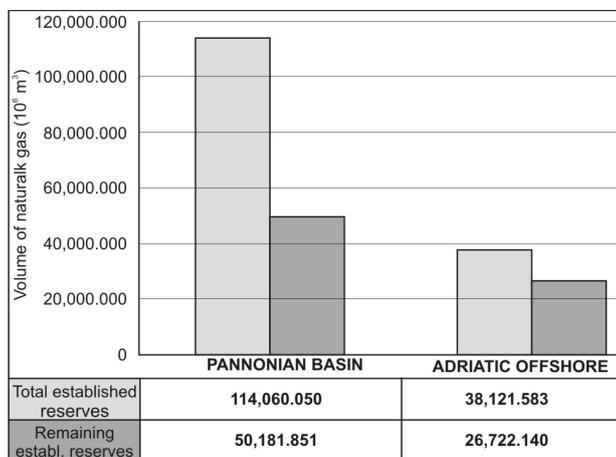


Figure 7 Total established and remaining established reserves of natural gas in the Pannonian Basin and the Adriatic offshore

Largest amount of established balance reserves, going from the largest, are located in the following fields: "Molve", "Sjeverni Jadran", "Kalinovac", "Žutica", "Bokšić-Klokočevci", "Okoli", "Marica", "Jamarica", "Lipovljani" and "Stružec" with almost 85 % of the proven balance reserves of natural gas.

When studying the volumes of remaining balance reserves, the situation is a bit different. Over 90 % of these reserves are from the following exploitation fields: "Sjeverni Jadran", "Molve", "Kalinovac", "Marica", "Izabela", "Gola", "Žutica" and "Vučkovec".

According to the established reserves and balance reserves data of the Republic of Croatia, the largest

proven volumes of natural gas are in the exploitation field "Molve" ($31\,397,271 \times 10^6 \text{ m}^3$) in the Drava depression (Tab. 3) and in the exploitation field "Sjeverni Jadran" ($29\,896,525 \times 10^6 \text{ m}^3$).

Order of exploitation fields, according to the amount of remaining established natural gas reserves is the same as with the established reserves only with a difference that the exploitation field "Sjeverni Jadran" has more remaining established reserves ($20\,043,592 \times 10^6 \text{ m}^3$) than the exploitation field "Molve" ($11\,472,125 \times 10^6 \text{ m}^3$). Therefore, "Sjeverni Jadran" has more remaining balance reserves (Tab. 3). Percentage of remaining balance in remaining total reserves in both exploitation fields is smaller than 50 % - 49,26 % in the exploitation field "Molve" and 44,50 % in the exploitation field "Sjeverni Jadran". Exploitation fields, according to the remaining total reserves, that follow after "Molve" and "Sjeverni Jadran" are: "Kalinovac" (Drava Depression), "Žutica" (Sava Depression) and "Marica" (Adriatic offshore). The Croatian part of the Pannonian Basin has nearly three times more established total reserves than the Croatian part of the Adriatic offshore (Fig. 7).

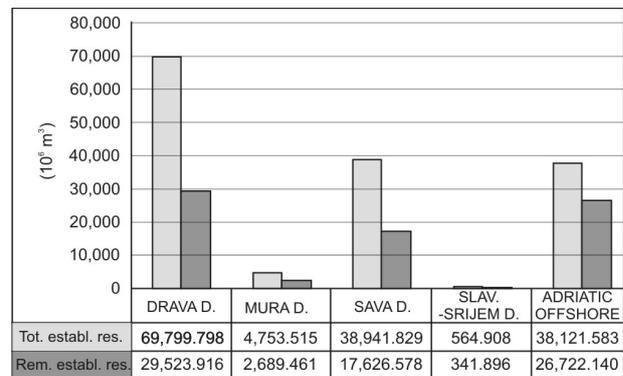


Figure 8 Total established and remaining reserves on the 31st of December 2010

Amounts of the remaining total reserves are nearly two times larger in the Croatian part of the Pannonian Basin than in the Croatian part of the Adriatic offshore in which exploitation started relatively recently while the fields in the Pannonian Basin have already been in exploitation for a long time period and are thus near the end of their exploitation period. At the moment, only a fifth of the discovered balance reserves are remaining in the Pannonian Basin area while in the Adriatic offshore nearly a half of the balance reserves are exploited up to date (Fig 9). In the Pannonian Basin the largest volumes of remaining total established balance reserves are found in the exploitation fields "Molve", "Kalinovac" and "Žutica". If only remaining balance reserves are observed then larger amounts of these reserves can be found in the "Molve" and "Kalinovac" exploitation fields (Tab. 3).

Drava Depression holds the leading position in volumes of total established balance reserves (50,62 %). When observing the remaining balance reserves then it has a leading place if observing the Pannonian Basin area (Fig. 10). According to the remaining total established reserves the Drava Depression has the largest volumes – 38,9 % of the Republic of Croatia remaining total established reserves (Fig. 8).

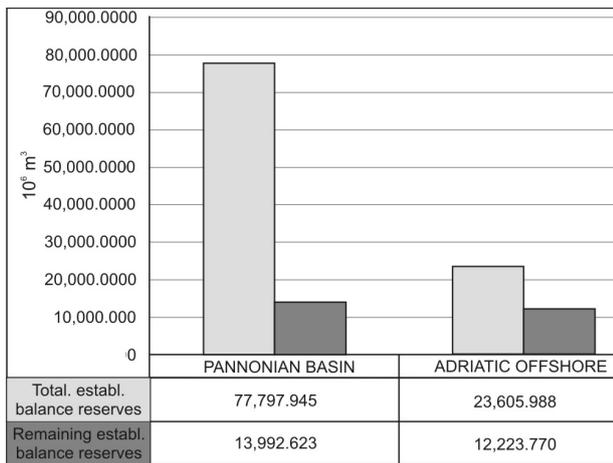


Figure 9 Total established balance and remaining established balance reserves in the Pannonian Basin area and the Adriatic offshore

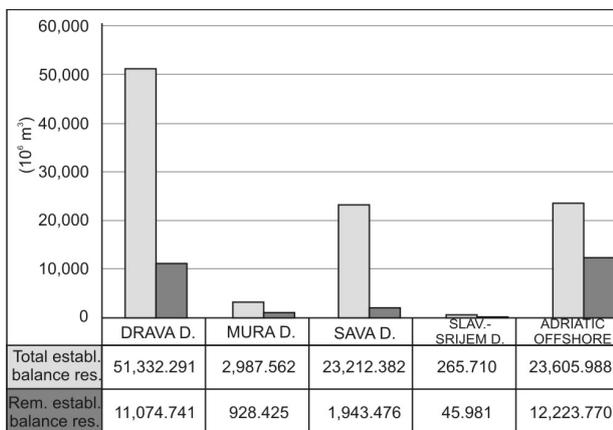


Figure 10 Established and remaining balance reserves of natural gas for depressions

Second in line, according to the volume of established reserves in the Pannonian Basin area, is the **Sava Depression**. It is also second according to the remaining total reserves in the Pannonian Basin area and third, behind the Adriatic offshore, when the whole area of the Republic of Croatia is considered. "Žutica", "Kloštar", "Jamarica", "Stručec" and "Okoli" are the most important exploitation fields according to the remaining balance and total established reserves in the Sava Depression. Also, it has to be mentioned that the

exploitation field "Kloštar" has a very small part of the remaining balance reserves in its total established reserves, thus the most influential exploitation field in this Depression is "Žutica" when the remaining balance reserves are observed.

From the remaining two small Depressions in Croatian part of the Pannonian Basin, the **Mura Depression** is more significant according to the established reserves of natural gas (Fig. 8). It holds just over 4 % of total established and remaining established reserves of the Pannonian Basin area or 3 % when the Adriatic offshore reserves are also taken into consideration (Fig. 8). Most significant exploitation fields in this area according to the total and remaining established reserves are: "Legrad", "Vučkovec", "Veliki Otok", "Kutnjak-Đelekovec" and "Zebanec". Today, exploitation field "Veliki Otok" does not have any more balance reserves while "Vučkovec" and "Zebanec" have the largest volumes of remaining balance reserves.

The Slavonia-Srijem Depression has the least amounts of the total established and remaining established reserves of natural gas – only 0,4 % (Fig. 8). The statistics are not any better if only the Pannonian Basin area is observed. Then the Slavonia-Srijem Depression holds only 0,51 % of the total established and 0,72 % of the remaining established reserves. There are three exploitation fields of which "Đeletovci" are the largest but none is of great significance in the volumes of natural gas reserves in the Republic of Croatia.

Last but not least, the Adriatic offshore holds the most interesting natural gas fields at present. Exploitation area "Sjeverni Jadran" holds the largest volumes of the remaining balance reserves. According to the volumes of total established reserves, the Adriatic offshore holds the second place in the reserves of the Republic of Croatia with 25,05 % (Fig. 8). The Adriatic offshore share in the volumes of remaining total reserves of natural gas is much greater with 34,75 % (Fig. 8) which makes it most perspective future exploitation area. It is also important that the remaining established reserves ($26\,722,140 \times 10^6 \text{ m}^3$) of the Adriatic offshore are nearly two times smaller than the remaining established reserves of the Croatian part of the Pannonian Basin which are shown in Fig. 7.

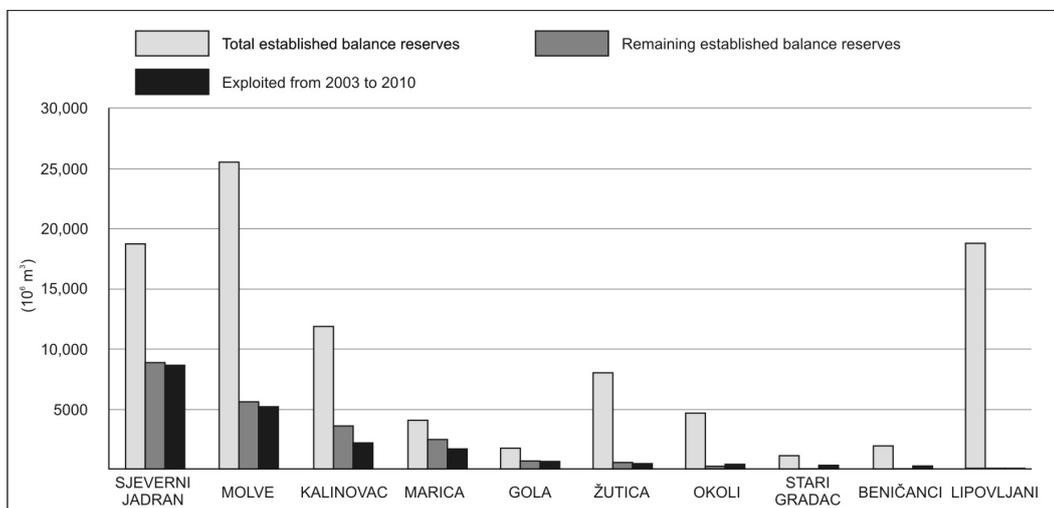


Figure 11 Overview of the natural gas exploitation in 10 exploitation fields according to volume of gas exploited from 2003 to 2010

Table 3 Total established and remaining reserves of natural gas of the 10 most significant exploitation fields in the Republic of Croatia

Exploitation field	Total established reserves		Remaining established reserves	
	Balance (10 ⁶ m ³)	Out of balance (10 ⁶ m ³)	Balance (10 ⁶ m ³)	Out of balance (10 ⁶ m ³)
MOLVE	25 575,960	5 821,311	5 650,814	5 821,311
SJEVERNI JADRAN	18 755,912	11 140,613	8 920,204	11 123,388
KALINOVAC	11 949,831	2 025,694	3 578,041	2 025,694
ŽUTICA	8 122,569	5 874,066	627,108	5 830,385
BOKŠIĆ-KLOKOČEVCI	4 844,700	1 583,941	0,056	1 576,795
OKOLI	4 755,760	1 390,830	237,559	1 390,830
MARICA	4 109,380	1 746,750	2 562,870	1 746,750
JAMARICA	2 693,802	2 008,600	97,228	2 008,600
LIPOVLJANI	2 046,185	850,796	60,588	850,796
STRUŽEC	1 991,840	1 366,210	266,553	1 366,168

Natural gas recovery in Croatian part of the Pannonian Basin is today over 55 % - by 31st of December 2010 63 805,322×10⁶ m³ of natural gas was exploited out of 114 060,050×10⁶ m³ total established reserves. Planned recovery is 68 % with exploitation of the remaining 13 992,623×10⁶ m³ of natural gas balance reserves. From the recovery ratios, it is obvious that in this area a huge amount of natural gas balance reserves has already been exploited.

Natural gas recovery in Croatian part of the Adriatic offshore is around 30 % - by 31st of December 2010 11 382,218×10⁶ m³ of natural gas was exploited out of 38 121,583×10⁶ m³ total established reserves. Planned recovery is 62 % with the exploitation of the remaining 12 223,770×10⁶ m³ of natural gas balance reserves.

From the aforementioned realized and planned recovery of natural gas, the exploitation period should be longer in the Adriatic offshore than in the Pannonian Basin but, because of the predicted dynamic of exploitation, natural gas reserves should be exploited sooner than the ones in the Pannonian Basin area.

In the eight year exploitation period, exploitation fields shown in Fig. 11 were the source of the majority of exploited natural gas. It should also be taken into consideration that over 60 % was exploited from the exploitation fields "Sjeverni Jadran" and "Molve" (Fig. 11). The remaining eight most significant exploitation fields are "Kalinovac", "Marica", "Gola", "Žutica", "Okoli", "Stari Gradac", "Beničanci" and "Lipovljani". Other than "Sjeverni Jadran", "Kalinovac", "Beničanci" and "Marica", the remaining exploitation fields have very low reserves left.

6 Conclusion

Future exploitation and consumption of natural gas in the Republic of Croatia were predicted by using near past trends and by a petroleum geology approach.

Reserves of natural gas in the Croatian part of the Pannonian Basin and in the Croatian part of the Adriatic offshore were determined in 60 fields. From 2003 until the end of 2010 exploitation of natural gas was active in 49 fields. In this eight year time period a total of 21 427,128×10⁶ m³ of natural gas were exploited with average exploitation of 7 203,140×10³ m³ per day. **The first conclusion** is that a negative trend is apparent in the

exploited volumes of natural gas in every depression in the Pannonian Basin while in the Adriatic offshore the trend is opposite.

The Republic of Croatia has 76 903.991×10⁶ m³ of the remaining total established reserves of natural gas, two thirds of which belong to the Pannonian Basin area and one third to the Adriatic offshore. The remaining balance reserves of the Republic of Croatia are 26 216,393×10⁶ m³. Of these 12 223,770×10⁶ m³ are from the Adriatic offshore and 13 992,623×10⁶ m³ from the Pannonian Basin area.

The second conclusion is that the estimated decrease in domestic exploitation of natural gas by 2014 will be such that the volumes of exploited and imported volumes of natural gas will be nearly the same. **The third conclusion** is that new solutions for the importation of natural gas are needed. Estimated import volumes of natural gas in 2030 are 7×10⁹ m³.

Length of the natural gas transport system in the Republic of Croatia is 2113 km. **The fourth conclusion** is that future difficulties in the importation of natural gas can be avoided by building new regional pipelines or by liquefied natural gas (LNG) terminals on the coastline as an alternative. **The fifth conclusion** is that the LNG terminal is less costly and a safer solution than pipelines. This is especially emphasized in global trends where the rising trend of LNG industry is apparent. Today it makes 21 % with an estimated one third by 2020 of the traded natural gas volumes in the whole world.

Acknowledgements

The authors would like to thank the Ministry of Economy, Labour and Entrepreneurship for the supplied data and for the financial support from the Ministry of Science, Education and Sports of the Republic of Croatia under the project "Stratigraphical and geomathematical researches of petroleum geological systems in Croatia" (project no. 195-1951293-0237).

7 References

- [1] Jović, G.; Cvetković, M.; Malvić, T.; Velić, J. Odnos rezervi i proizvodnje ugljikovodika po dekadama i dominantnim ležišnim litologijama u hrvatskom dijelu Panonskog bazena. // 4. hrvatski geološki kongres - Knjiga

- sažetaka / uredila Marija Horvat. Zagreb : Hrvatski geološki institut, 2010. pp. 272-273.
- [2] Velić, J.; Malvić, T.; Cvetković, M.; Weisser, M.; Curi, V. Observation useful for increase of hydrocarbon fields exploitation period within Croatian part of the Pannonian basin. // *Modern Management of Mine Producing Geology and Environmental Protection / Edited by International Scientific Committee of SGEM. Sofia : International Scientific Conference SGEM, 2008. pp. 567-574.*
- [3] Velić, J.; Malvić, T.; Cvetković, M.; Vrbanac, B. Characteristics of Hydrocarbon Fields in the Croatian Part of the Pannonian Basin. // *Oil, gas European Magazine. 36, 3(2010), pp. 146-147.*
- [4] Narodne Novine. Pravilnik o prikupljanju podataka, načinu evidentiranja i utvrđivanja rezervi mineralnih sirovina te o izradi bilance tih rezervi. // *Narodne Novine d.d., 48(1992).*
- [5] Narodne Novine. Ispravak Pravilnika o prikupljanju podataka, načinu evidentiranja i utvrđivanja rezervi mineralnih sirovina te o izradi bilance tih rezervi. // *Narodne Novine d.d., 60(1992).*

Authors' addresses

Josipa Velić, prof. dr. sc.

Faculty of Mining, Geology and Petroleum Engineering
Department of Geology and Geological Engineering
Pierottijeva 6, 10000 Zagreb, Croatia
Contact: Tel 0038515535777/Fax 0038514836064
josipa.velic@rgn.hr

Dragan Krsić, dr. sc.

Ministry of Economy, Labour and Entrepreneurship
Directorate of Mining
Ulica grada Vukovara 78, 10000 Zagreb, Croatia
Contact: Tel 0038516106972/Fax 0038516109113
dragan.krsic@mingorp.hr

Ivan Kovačević

Faculty of Mining, Geology and Petroleum Engineering
Pierottijeva 6, 10000 Zagreb, Croatia